



Synthesis

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Chapter 3

Synthesis

Global wind energy perspectives

→ Global annual installed wind power capacity in 2013 amounted to a little more than 36 GW, a decrease of approximately 20% compared to 2012. Over the past ten years, global accumulated installed wind power capacity has increased from approximately 48 GW in 2004 to around 320 GW at the end of 2013, an average annual growth in the order of 20%.

Several studies indicate that onshore wind installed capacity will exceed 1,000 GW in 2030. And offshore wind capacity might exceed 200 GW. Countries with the largest expected share of wind energy in their power systems in 2030 include Denmark, the leader, which is expected to produce more than 60% of its electricity from wind, followed by Germany and the UK, which may reach shares of 40–50%.



Danish and European plans for wind energy deployment

→ Denmark has a goal of supplying 50% of its domestic power consumption from wind by 2020.

The European Technology Platform for Wind Energy (TPWind) sees wind energy as the leading renewable energy technology which could provide up to one third of EU electricity by 2030.

The focus in EU research funding for wind energy has shifted towards more strategic long-term collaboration, in order to create clearer links between nationally funded projects and those with EU support.

Wind energy developments

→ In spite of the slowdown in global markets, recent years have seen renewed effort in the technological development of wind turbine technology. This effort is driven by stronger global competition within the wind energy sector as well as the competing energy technologies. This competition provides a pull towards lower cost of energy (CoE), larger and more reliable wind turbines for offshore applications, and an increased interest in developing sites with low or moderate wind regimes. Thus the mainstream development trend in turbine technology is characterised by scaling up to turbines of larger rated capacity for both onshore and offshore applications,

larger rotors for higher capacity factors, and new drive train solutions, including direct-drive turbines without gearboxes.

The technology solutions are strongly influenced by the development of the international wind industry, with its global market for components. Contrary to what was expected a few years ago, the market has not consolidated into just a few large suppliers. The top ten companies supply 69.5% of the market, and the next five largest suppliers, all from China, provide an additional 13.4%.

Onshore wind power is becoming increasingly competitive with conventional fossil-based electricity generation.

The shares of turbine costs, installation costs, infrastructure costs, and operating costs in the levelized cost of energy (LCoE), (the price at which electricity must be generated from a specific source to break even over the lifetime of the project) depend on the project type: the turbine cost is typically more than half the total for onshore projects, but less than half for offshore projects.

The typical power of onshore turbines is 2–3 MW, whereas the largest offshore turbines range up to 8 MW and have rotor diameters up to 171 m. The same rotor size may be used for turbines with quite different power ratings, if these are targeted at different wind conditions. It is preferable to have a turbine producing a lower full rated power, for more days in a year, than

to have high power production for only a few days a year.

Offshore wind energy developments

→ Offshore wind power is still much more expensive than its onshore counterpart. The reasons for going offshore are many, but mostly relate to higher wind resources, less environmental impact and more available space. The drawbacks are increased operation and maintenance costs, and added capital expenditure, for instance for cabling and support structures.

The most important short- to medium-term goal for the offshore wind industry is to lower LCoE. Offshore CoE can be reduced through upscaling of turbines and industrialisation of other parts of the plant, and the industry is on track to achieve its target of cutting costs by approximately 40% by 2020.

The evaluation of the CoE from offshore wind power must include the cost of the foundation, which will scale with the water depth of a specific installation site. Additionally it will scale with the rotor size, since the larger rotor creates bigger loads and hence needs a foundation that is both wider and thicker. Although the foundation is often more expensive than the turbine itself, its cost scales more slowly as the turbine size increases. As a result, it turns out that turbines much larger (>5 MW) than the current onshore size of 2–3 MW are more economical offshore due to the foundation cost.

Substantial research and development is needed to realise the Danish vision known as MegaVind, a public-private cooperation between the state, industry,

universities and venture capitalists to accelerate innovation in wind energy. To make MegaVind work, research needs to focus on those areas where RD&D is most cost-competitive:

- design;
- site conditions;
- support structures;
- reliability and operation and maintenance (O&M);
- project development and planning;
- business innovation; and
- standards and certification.

Upgrading offshore grids

The architecture favoured for the collection grids of offshore wind farms and their cable connections to land is expected to evolve from the 33 kV AC cables used at present. Future systems are likely to operate at 66 kV AC and above. Another possibility is DC collection grids linked to shore via either HVAC (high voltage alternating current) or HVDC (high voltage direct current) export cables, especially as the offshore distance increases.

Offshore wind farms connected to the grid through HVDC converters can play an important role in supporting grid performance. Converters can also contribute to short-term stabilisation if they are combined with suitable energy sources.

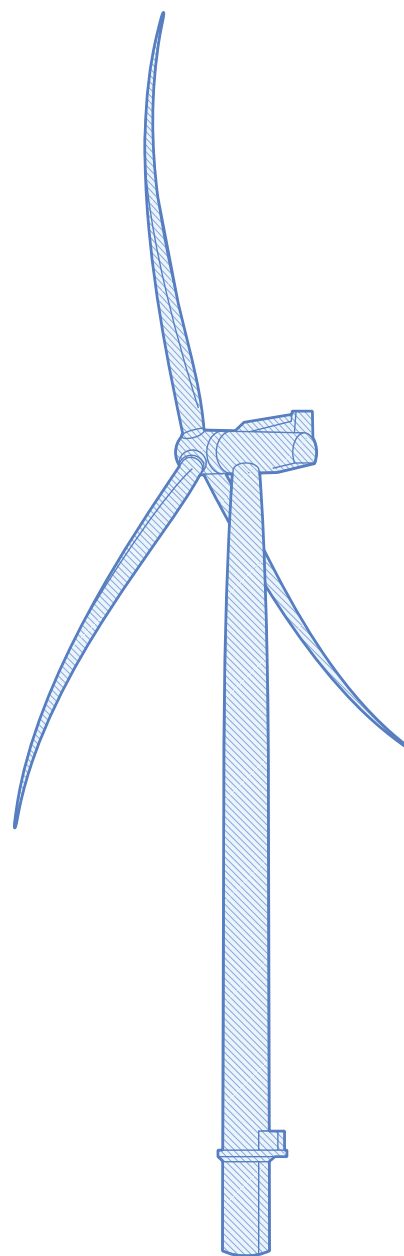
Lowering costs of offshore wind services

Offshore wind services (ows) are the services needed to install, operate, maintain, and decommission or repower an offshore wind farm through its life cycle. Over the life cycle of an offshore wind farm the actual O&M cost is estimated to account for 25–28% of the total LCoE. The opportunities to lower costs here include standardising technologies and

interfaces; improving communication and knowledge exchange within the ows value chain; and securing the skills and qualifications necessary to provide ows safely, effectively and efficiently.

Standards and certification remove barriers

→ Much of the technology development and globalisation we have seen in the wind energy industry has been helped immensely by the development of international standards. Standards can be used to share new technical knowledge and best practices, and to facilitate technical development by creating and maintaining an

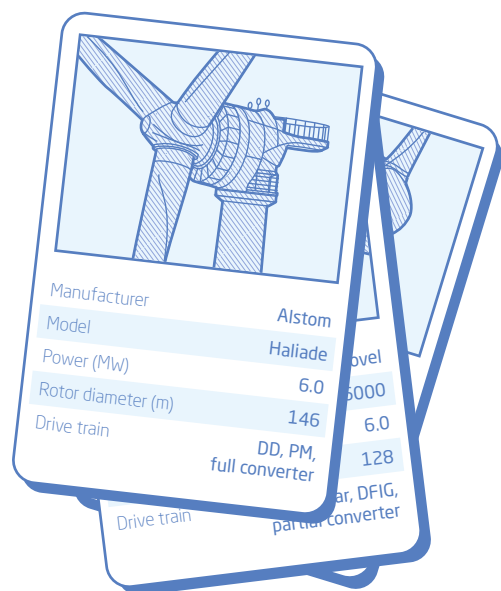


international market without technical barriers. However, increasingly comprehensive technical standards can also become a barrier to technical development.

Emerging wind energy technologies

→ Since the wind industry took off in the mid-1980s, wind turbine technology has seen rapid development. This has led to impressive increases in the size of turbines over the last three decades – power output has risen by a factor of about 100 – accompanied by major cost reductions thanks to optimised and relatively lightweight designs. If a 55 kW turbine from the mid-1980s were directly scaled up, for instance, the newest 6–8 MW turbines would weigh about 10 times as much as they actually do.

Most emerging technologies of the wind sector are addressing technical challenges, which are limiting a decrease of the cost-of-energy (CoE). Strategies for decreasing CoE focusses on building cheaper hardware that last for the lifetime of the installation with as small maintenance as possible and at the same time harvesting as much energy as possible.



To lower the CoE, designers have tailored the turbines even more carefully to the conditions under which they operate; advanced designs using less materials and higher reliability remain the main ways of reducing CoE for future turbine designs.

Scaling up for more power and higher income

→ The power, and hence the income, from a turbine increases with the area of the rotor. As blades are made longer, however, their mass grows faster than the area of the rotor. This relationship, often called the “square-cube” law, indicates that CoE should increase with blade length.

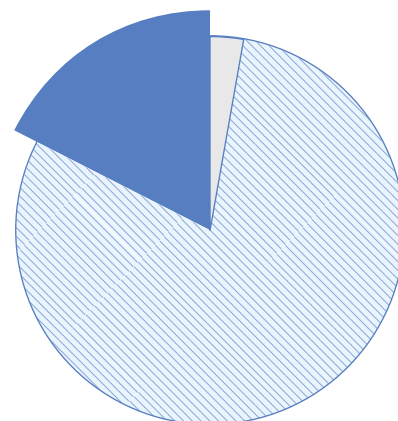
In fact, this has not been the case for several decades due to advances in blade materials and designers’ ability to optimise their aerodynamic and structural properties. The typical power of onshore turbines is now 2–3 MW, whereas the largest offshore turbines range up to 8 MW.

Lighter blades with unconventional shapes

Many factors have aided the move to lighter blades, of which the most important has been the development of blades that are much more slender and flexible than their predecessors. This development is leading to blades with new geometry with passive control, advanced thick airfoils and new processes and materials.

Drive trains without gears

Conventional wind turbines use gears. Several manufactures have now introduced direct drive generators, which require no gearbox. The advantage is a simpler machine with fewer moving parts and hence improved reliability.



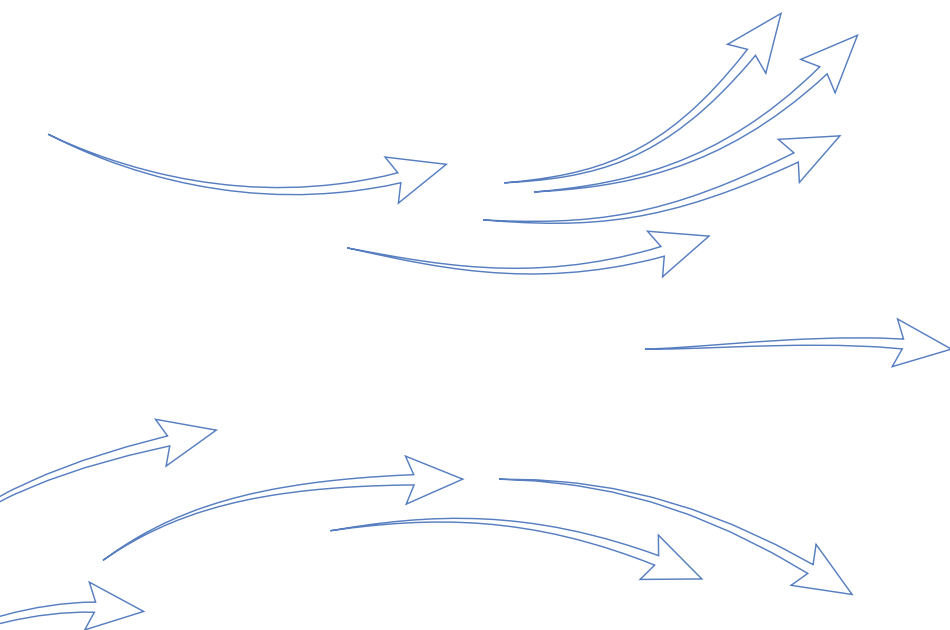
Towers

As the rotor diameter increases, so the tower has to become not only taller but also wider and thicker to mitigate the load from the rotor to the foundation. Currently most towers are made of steel plates. The sections are lifted on top of one another and bolted together to form the final tower. Handling these plates is posing an increasing challenge and several new concepts are looking into other materials. New concepts for towers include building them from serially produced concrete segments.

Challenges and solutions for energy systems with high shares of wind energy

→ The integration of wind power into today’s energy systems has several related, but separate, aspects.

One of these is network integration. Wind power plants are typically located where the best wind resources are, but these sites rarely coincide with the location of electricity consumers and large existing grid capacities. With ever-increasing shares of wind energy in the system the existing grid infrastructure is becoming challenged in some regions, at both medium and high voltages.



Another aspect relates to long-term and medium-term integration. Production from wind power plants can be highly variable, depending on the availability of the wind resource.

The inherent uncertainty of wind power generation leads to deviations between forecast and actual wind production, and hence to unexpected fluctuations in the power supply. To minimise the effect of these fluctuations the system operator needs access to sufficient reserves. A high share of wind energy also means that wind energy must take a larger responsibility for the stable operation of the energy system and provide system services, which are known as ancillary services.

To balance energy systems with very high shares of wind energy it is necessary to have well-integrated grids with good interconnections to reduce balancing needs. Demand response, meanwhile, will reduce balancing needs on the supply side. Electrical storage can provide additional control capacity that could replace the need for flexible thermal

power generation. Wind power plants themselves can also deliver some of the ancillary services.

The large-scale integration of wind energy into power systems will require integrated regulation strategies for the whole energy system, and these strategies will in turn draw from all the options mentioned above. Wind power plants will not only have to produce energy, but also contribute to delivering ancillary services.

Improved forecasting reduces uncertainty

→ To reduce uncertainty in wind energy production a new European Wind Atlas will address such issues as the predictability of wind, turbulence and loads on the wind turbines, the probability of icing, and other weather-related influences on the installation or operating cost of wind power plants.

Wind power forecasts have historically focused on methodologies for predicting

generation at hourly intervals, because this is the shortest timescale on which electricity is traded in the existing markets. However, experts in energy management have argued that decreasing the scheduling time for generation and delivery from hours to minutes would greatly facilitate the balancing of electricity production and consumption.

There is a long tradition of using “point forecasts” of wind power generation for dispatching and trading. However, such simple forecasts are known to be sub-optimal for many operational problems. Nowadays the focus is moving towards new research areas such as frameworks for probabilistic estimation, and the use of probabilistic forecasts to aid decisions about electricity markets.

The most advanced type of forecast product is a scenario. This describes, for example, how the power output of a particular wind farm is likely to vary over time. Scenarios have been widely used by researchers and practitioners to model wind power and to build advanced tools for operating and planning energy systems.

New approaches to wind economics

→ For wind power, a number of EU countries leave the classic feed-in tariffs that paved the way for the cost reductions we have seen to date. One of the main reasons is wind’s increasing market share: wind power now has to interact better with the remainder of the power system, and should react to market signals.

The EU’s current legislative plans point towards a stronger focus on cost reduction and competition. This might be achieved by the wider use of tendering as a support

tool; tendering is currently used to determine offshore support rates in France, for example. Moreover, cross-border cooperation as established by an EU Directive sees the light of day.

The capital costs of wind energy projects are dominated by the costs of the turbines themselves. Of the other cost components, the dominant ones are grid connection, electrical installation, and foundations. These auxiliary costs vary considerably, ranging from 20% to 30% of the total turbine costs.

For a standard onshore installation with an investment cost of 1,750 \$/kW the cost ranges from approximately 7–9 US cent/kWh at sites with low to medium average wind speeds, to approximately 6–7 US cent/kWh in good coastal positions.

Energy from offshore turbines is considerably more expensive than that from onshore turbines. At a high-wind offshore position with a capacity factor of 50%, corresponding to wind conditions at the Danish Horns Reef 1 wind farm, the calculated cost of electricity is close to 12 US cent/kWh for a standard offshore installation with an investment cost of \$3,900/kW.

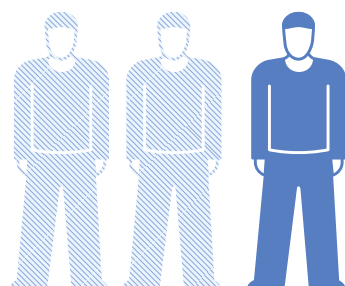
O&M costs are increasingly attracting more attention. Manufacturers are attempting to lower these significantly by developing new turbine designs requiring fewer regular service visits and less planned downtime for maintenance.

Wind power creates jobs

→ Most forecasts agree that the wind energy market will grow with respect to installed new capacity, repowering, and O&M. The European Wind Energy Association (EWEA) estimates that by 2020 there will be 520,000 jobs in the European wind energy sector and almost 800,000 jobs by 2030. The wind power industry is thus an important driver in the creation of new jobs.

Globally 834,000 people were employed in the wind industry at the end of 2013 – a rise of 11% compared to 2012. The highest growth is seen in emerging countries such as China, where 365,000 people worked in the wind industry by the end of 2013 – a rise of 37% compared to 2012.

There has been a shift from jobs requiring unskilled labour to those that are highly skilled. In particular, jobs at master's and PhD levels have grown consistently, and only unskilled job have fallen recently. Highly trained staff is scarce, however, and increasing the supply of skilled labour will require determined effort in education and research. The European wind industry is already finding it difficult to hire suitably trained staff.



Environmental and social impacts of wind energy

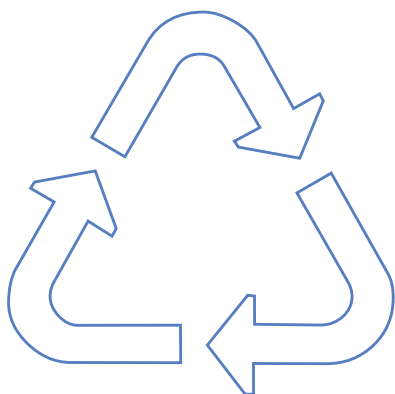
→ Compliance of wind farms with local and regional environmental requirements and guidelines, and social acceptance, are prerequisites if wind power is to meet its ambitious targets for growth.

To date only a limited amount of research has been done on the aesthetic impact of wind turbines on landscapes. No issue seems to be argued more strongly than that of landscape. Noise, another potential problem, is partially subjective in the way it affects people's perceived quality of life. Finally, the issue of shadow flicker requires a clear sky, a low sun, wind, and a particular wind direction in relation to the position of the sun and the observer.

Social acceptance of wind turbines

For land-based developments, governments have tended to focus their attention on overcoming the initial and obvious challenges of designing an appropriate support system, securing grid access, simplifying complicated planning procedures and dealing with technical risks. But in many countries it is now becoming clear that the degree of social acceptance will determine the ultimate scale of the onshore wind industry.

Recent research in Denmark is looking towards new opportunities to understand and improve the democratic processes linked to the construction of large wind farms and other renewable energy plants. A new Danish method of clarifying public concerns and ensuring that more views come to the fore has recently been applied.



Recycling of wind turbines attracts greater attention

→ The end-of-life options for wind turbines are second-hand markets, refurbishing, recycling, and depositing. Blades are a major headache in the removal and recycling of wind turbines, and there is much uncertainty about how to get rid of them properly and safely. Electronic equipment is also a problem, since as much as 50% goes to landfill. Most life cycle assessment (LCA) and recycling studies of wind turbines focus on the blades, but there seems to be a need for more knowledge of how to recycle not only electronics but also other composite components like cables and hydraulic cabling.

The institutional and organisational structures relating to the dismantling and recycling of wind turbines are still quite uncertain.

Studies point out that there is a need to develop policies encouraging the recyclability of wind turbines, and to stimulate markets for second-hand turbines as well as the growth of independent operators.

Technologies for recycling composite materials are now available, but the investment and operating costs mean that recovered glass fibres are currently more expensive than pristine ones. Commercial applications have therefore been very limited.